1503

INSTRUCTIONS AND APPLICATIONS

Deviation Bridge Type 1503

Adapted for the checking of resistors, capacitors and inductors, in industrial production and laboratories.

- Acoustic standing wave apparatus
- Artificial ears
- Artificial voices
- Audio frequency spectrometers
- Audio frequency voltmeters
- Automatic A. F. spectrum recorders
- Automatic frequency response recorders
- Beat frequency oscillators
- Condenser microphones
- Deviation bridges
- Distortion measuring bridges
- Electronic counters
- Frequency analyzers
- Frequency measuring bridges
- Frequency response tracers
- Hearing aid test apparatus
- Heterodyne voltmeters
- Level recorders
- Megohmmeters
- Microphone amplifiers
- Microphone calibration apparatus
- Noise sources
- Polar diagram recorders
- Preamplifiers
- Recording paper
- Rotary selectors
- Strain gauge apparatus and accessories
- Surface roughness meters
- Vibration pick-ups
- Wide range vacuum tube voltmeters

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Deviation Test Bridge

Type 1503

APRIL 1959

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Description.

General.

The Deviation Bridge Type 1503 is specially designed for production control of resistors, capacitors and inductors, but is also a very useful instrument for laboratory purposes.

It consists of a Wheatstone Bridge with two fixed resistors, and two sets of input terminals for connection of an external standard and the unknown component. The bridge is operated from a built-in generator. The diagonal voltage is, via a two-stage amplifier, fed to a phase-sensitive demodulator, the output voltage of which is measured on a moving coil instrument with big, interchangeable scales. The scale-reading is the positive and negative deviation in per cent and the positive and negative phase angle in radians between the standard and the unknown component. The connection of the

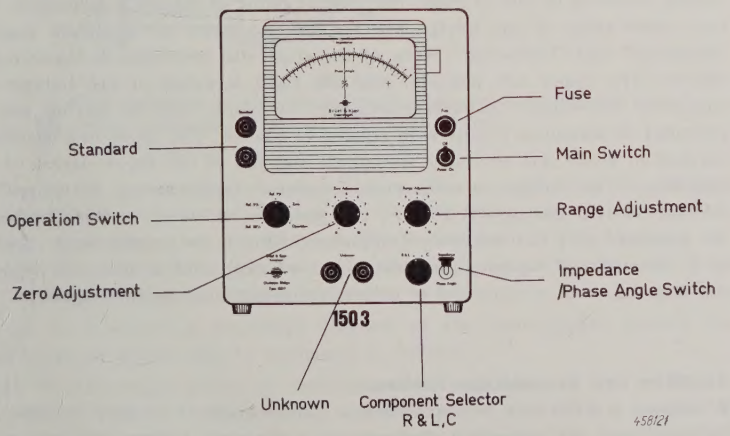


Fig. 1. Front view of the Deviation Bridge Type 1503.

unknown component to the Bridge terminals is very rapidly performed, when the Test Jig Type 3902 is used.
Four calibrated, and two blank scales for special calibration purposes are supplied with the Bridge.

Oscillator and Bridge Section.
The built-in oscillator, which is of the Hartley type, operates at a frequency of 100 c/s. The output voltage is fed to an output amplifier via a resistor or a R-C network. The selection is made by means of the switch marked "Impedance/Phase Angle". When switched in, the R-C network introduces a 90° shift in the output signal for the purpose of phase angle measurement as described on page 7.
Via a potentiometer marked "Range Adjustment" the signal is fed to the output amplifier, consisting of a triode and a pentode in cascade. In order to avoid any phase shift in being produced in this stage, the load must be true resistive. By parallelling the output transformer with a capacitor the anode circuit may be adjusted to the bridge frequency, whereby the said condition is obtained. This is only true when the secondary load of the transformer is resistive. By a capacitive load (i.e. when measurements are carried out on capacitors) the small extra phase shift causes an error, which may be corrected for by employing the table given on page 18.
From the output transformer also a great amount of negative feed-back is supplied to the cathode circuit of the preceeding amplifier stage, whereby a very low output impedance of the amplifier (approx. 0,3 Ω) is obtained.
The two fixed resistors incorporated in the Wheatstone Bridge are wire-wound resistors of 100 Ω each, the mutual point of which is grounded. The two other arms of the bridge are fed to two pairs of terminals marked "Standard" and "Unknown". None of the apparatus terminals is connected to chassis. The upper left terminal and the right terminal at the bottom are connected to chassis through resistances of about 100 Ω, having an AC potential of maximum 2 volts with respect to chassis. The other two terminals, marked in white, are mutually connected and led to the input circuit of the amplifier. The bridge arrangement involves, furthermore, a component selector switch marked "R & L/C", the purpose of which is to interchange the standard and the unknown component. This is to permit direct reading in % deviation of capacity (and not of impedance), and is necessary because the impedance of a capacitor is inversely proportional to the capacity.

Amplifier and Demodulator Section.
Whenever a difference in magnitude or phase angle is present between the standard and the unknown component, a diagonal voltage occurs in the bridge arrangement. This voltage is fed directly to the input of a two stage

resistance coupled amplifier, which is supplied with negative feedback to obtain a stable operation and a high input impedance. (When measuring too high impedance values, the input impedance of the amplifier will load the bridge, and consequently cause erroneous measurements. See correction curves on page 21). The output of the amplifier is connected to a demodulation circuit which, to a certain degree, makes the instrument insensitive to hum and noise voltages, because the demodulator preferably responds to signals of the same frequency as that of the oscillator. Furthermore, positive and negative deflections are obtained for positive or negative deviations from the standard, respectively.

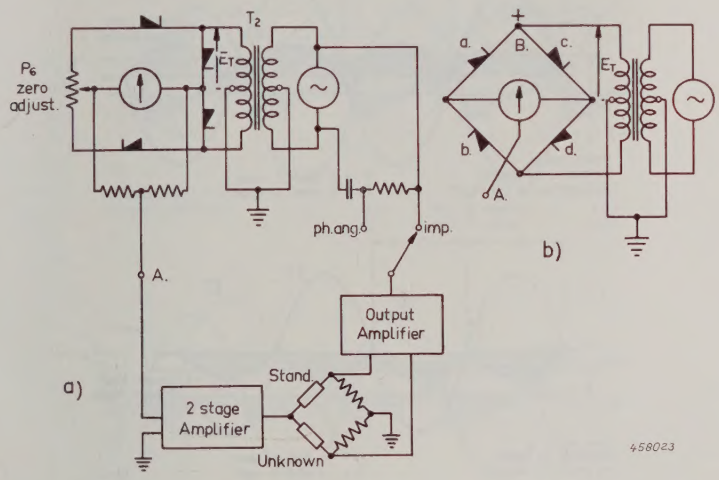


Fig. 2.
a) Working principle of the Deviation Bridge and demodulator circuit.
b) Simplified schematic of the demodulator circuit.

In fig. 2a the demodulator circuit is shown. The potentiometer P_6 (marked "Zero Adjusiment") can be adjusted to a position where no current will flow through the meter when no signal is fed to the point A. The point A represents the output from the two stage amplifier, and as can be seen from fig. 2a, also the electrical mid-point of the meter.

In fig. 2b is shown a simplified diagram of the demodulator circuit, the functioning of which may be explained as follows:

When the AC voltage across the transformer has a polarity as seen in fig. 2b, the cells "c" and "d" will open. If a signal *in phase* with E_x (i.e. positive at the point A) is present, a current will flow from A through the meter and the cell "d" to ground, making the meter deflect to the right. When the point B

changes to be negative, the signal at A will also change to a negative value as both signals derive from the same oscillator. Now the cells "a" and "b" will be open, and a current will flow from ground through the cell "b" and the meter to A, again causing the meter to deflect to the right. This may be seen from the curves shown in fig. 3a, where t_1 indicates the time interval when the signals both are positive, and t_2 indicates the time interval when the signals are negative. As can be seen, the current in both cases flows in the same direction through the meter.

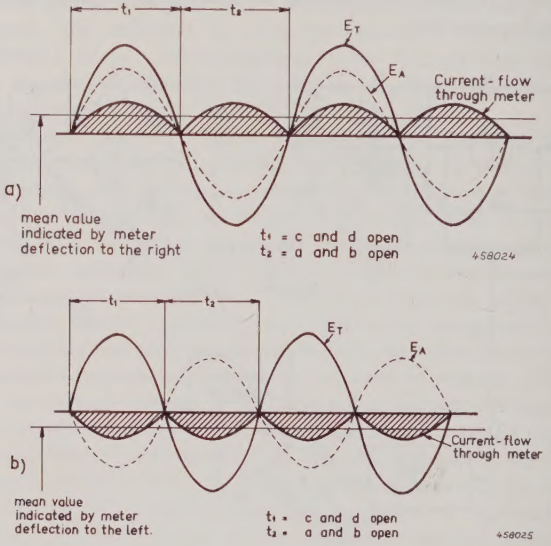


Fig. 3. Graphical representation of the demodulator voltages when measuring impedances.
a) Oscillator and bridge voltages in phase.
b) Oscillator and bridge voltages in antiphase.

If the signal at A is in *antiphase* with E_T, the point A will be negative, when the point B is positive, and the cells "c" and "d" are open. The negative signal at A will then cause a current to flow from ground through the cell "c" and the meter to A, making the meter deflect to the left. When B is negative, the cells "a" and "b" will be open, and the positive signal at A will cause a current flow from A through the meter and the cell "a" to ground, which again will make the meter deflect to the left. In fig. 3b the graphical representation of the current flow through the meter is shown, and by comparing this curve with the curve shown in fig. 3a it can be seen that meter deflections caused by signals in phase with E_T are always opposite to deflections caused by signals in antiphase with E_T.

The above described conditions count for pure impedance-measurements. When the bridge is used with the switch "Impedance/Phase Angle" in its "Phase Angle" position the voltage applied to the measuring bridge is 90° out of phase with the voltage E_T applied to the demodulator bridge. The current-flow through the meter will therefore be as indicated in fig. 4a, when no phase difference exists between the standard and the unknown impedance. As the mean value of the current is zero, there will be no meter deflection. When a phase angle deviation is introduced in the measuring bridge, the

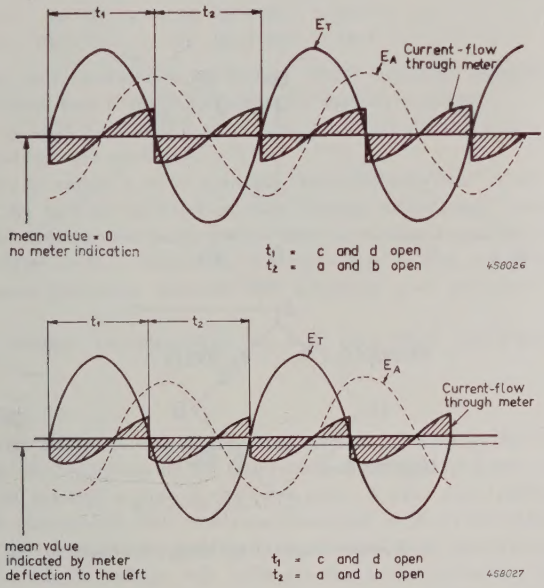


Fig. 4. Graphical representation of the demodulator voltages under phase angle measurements.
a) No phase angle deviation is represented at the measuring bridge.
b) Phase angle of "Unknown" is smaller than phase angle of "Standard".

voltage and current relationships will f. inst. be as shown in fig. 4b. In this case the phase angle of the unknown is the smaller one and the meter deflects to the left.

In fig. 5 a vector diagram of the voltages appearing in the Wheatstone Bridge arrangement during measurements is shown.

The vectors AB and BC represent the voltages across the two fixed resistors, respectively, the vectors AD and DC the voltages across the "standard" and the "unknown" impedances, and the vector BD the voltage applied to the amplifier.

When impedance measurements are taken only the voltage represented by the vector BD_1 is indicated by the meter.

For phase-angle measurements the meter indication will be proportional to the voltage BD_2.

It is seen from the diagram that the point D might move along a line drawn through the points D—D_1 without influencing the magnitude of the vector BD_1.

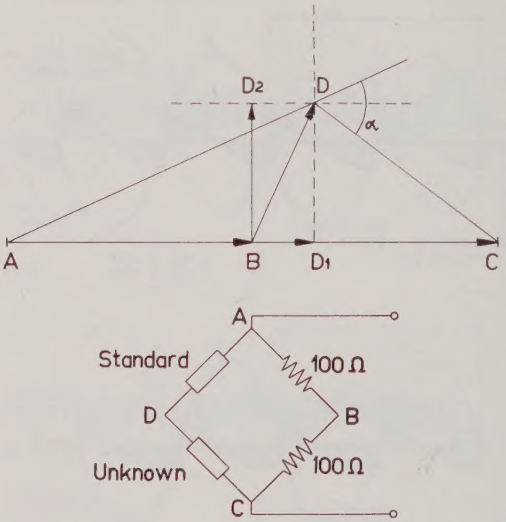


Fig. 5. Vector diagram of bridge voltages.

Similarly the magnitude of the vector BD_2 will not be influenced if the point D moves along a line drawn through the points D—D_2.

As the difference in phase angle between the "standard" and the "unknown" component is α (see fig. 5) this means that:

1. When the phase angle of the "unknown" is very much different from the phase angle of the "standard" the measurement of impedance deviation is inaccurate.
2. When the impedance of the "unknown" is very much different from the impedance of the "standard" the measurement of phase angle deviation will be inaccurate.

The maximum inaccuracy will be present when both phase angle and impedance measurements show maximum deviation between "standard" and "unknown".

Meter Section.

As previously mentioned, different dials can be inserted in the large square type indicating meter.

The four calibrated scales, supplied with the instrument cover the following ranges of deviation measurements:

Impedance Deviation	*Phase Angle (tan δ) Deviation*	*Range Adjustment*
— 1.5 % to + 1.6 %	— 1.5 to + 1.5 $\times 10^{-2}$	1 %
— 7 % to + 8 %	— 7 to + 7 $\times 10^{-2}$	5 %
— 25 % to + 35 %	— 30 to + 30 $\times 10^{-2}$	20 %
— 50 % to + 100 %	— 80 to + 80 $\times 10^{-2}$	20 %

The moving coil instrument is slightly under-critically damped to secure maximum speed, and is perfectly protected against overload.

To be able to calibrate the apparatus for the different ranges in a quick way, reference voltages are provided.

When the 1.5 % range is to be used the "Operation Switch" is set to position "Ref. 1 %". By turning the knob marked "Range Adjustment" until the meter pointer deflects to the red mark on the scale, a voltage is applied to the input of the amplifier, with a magnitude corresponding to the one obtained when the impedance deviation between the standard and unknown impedance is 1 %.

Reference voltages corresponding to 5 % and 20 % deflection are also available.

Power Supply.

The Deviation Bridge is intended for use with 115, 127, 150, 220 or 240 volts AC, 40—400 c/s. Switching to the different line voltages is made by means of a screwdriver through a hole in the back plate. A pilot disc indicates the line voltage to be connected. The power consumption is about 40 watts. The plate voltage to the oscillator is stabilized by a neon tube. A variation of 10 % in the power supply voltage will influence the meter deflection by less than 3 %, the zero point being independent of the line voltage.

Operation.

General.

During measurement it is advantageous to ground the apparatus.

The standard and the objects to be tested should be placed together with the bridge on a grounded metal plate.

If the object to be tested is grounded, the grounded pole should be connected to the right "Unknown" terminal, and the grounding of the cabinet of type 1503 be omitted. The capacity of the apparatus to ground is then connected across one of the built-in ratio resistors and should consequently be kept as low as possible.

When high impedances are being measured (large resistors and inductances. and small capacitors, respectively) the connections to the bridge should be kept short to reduce the influence of wiring capacity.
For measurements on small impedances the effect of the wiring resistance and inductance should be taken into account.
Furthermore, no extra capacity must be introduced between chassis and the two terminals marked in white.

Operation Procedure.

1. Make sure that the Deviation Bridge is adjusted to the correct mains voltage. If not turn the pilot disc on the rear panel of the instrument to the desired voltage (115 — 127 — 150 — 220 or 240 volt).
2. Connect the power cable to the mains and place the toggle switch marked "Power" in position "On". The light on the meter comes on immediately.
3. Allow a few minutes warm-up time.
4. Set the switch marked "Impedance/Phase Angle" in position "Impedance".
5. Place the meter scale corresponding to the desired measuring range (1.5 %, 8 %, 35 %, 100 %) in the meter frame. (The scale is removed from the frame by pulling to the right).
6. Turn the "Operation Switch" (knob to the left) to "Zero". By means of the knob marked "Zero Adjustment" the meter pointer is set to 0.
7. Connect the standard component to the terminals marked "Standard" and the component to be checked to the terminals "Unknown".
8. Set the "Operation Switch" to the desired Ref. value ("Ref. 1 %, "Ref. 5 %, or "Ref. 20 %"). Turn the knob marked "Range Adjustment" until the meter pointer deflects to the red mark on the scale.

Note:
When measuring high impedances, the values obtained from the adjustment curves, shown on p. 21, should be used for the range adjustments, instead of the red mark on the scale.

9. Turn the "Component Selector" to the correct position (for resistors and inductances to position "R & L" and for capacitors to position "C"). For the influence of capacitive loading see table 1 on page 18.
10. Turn the "Operation Switch" to position "Operation" and the instrument is ready for use.

Note:
If disturbing fluctuations of the meter pointer occur when measuring high impedances, the reason may be that the synchronization to the line frequency is improper connected. See Appendix page 18.

11. For *phase angle measurements* set the switch marked "Impedance/Phase Angle" in position "Phase Angle". It is locked in this position by pushing it downwards and to the left.

Note:
To avoid overloading of the amplifier a check should be made that the meter

deflection is kept within full scale deflection both with the press button switch in position "Impedance", and in position "Phase Angle".

12. The components to be tested are now sucessively connected to the two terminals marked "Unknown" and the meter deflection will give the deviation from the Standard directly in % or in radians $\times 10^{-2}$.

Deflection to the right means positive deviation (unknown bigger than standard), and deflection to the left negative deviation (unknown smaller than standard).

Test Jig Type 3902.

The Test Jig Type 3902 is designed to be used in connection with the Deviation Bridge for rapid production control of resistors, capacitors, and

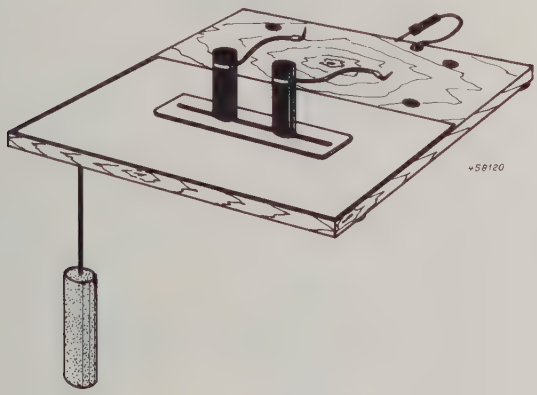


Fig. 6. Test Jig Type 3902.

inductors. It consists of a wooden board on which the Deviation Bridge should be placed. On the board in front of the instrument are placed two binding posts supplied with spring loaded contacts. The opening of the contacts is controlled by means of a lever, and the contacts can be directly connected to the terminals marked "Unknown". The lever is intended to be operated by means of the operators left knee. That part of the wooden board which is in front of the instrument, is, furthermore, supplied with a steel plate, which should be connected to the instrument cover and to ground. The distance between the posts is adjustable between 0 and 14 cm (5½ inches). The measurements are carried out by engaging the lever for operating the contacts, placing the component to be measured between the two posts, and releasing the lever. The instrument then immediately shows the deviation from the standard-component employed.

Applications.

Production Control of Electrolytic Capacitors.

The Deviation Test Bridge Type 1503 used in connection with the Test Jig Type 3902 performs a measuring instrument which is very well suited for rapid and accurate production line tests of electrolytic capacitors and other large size capacitors. Fig. 7 shows a practical arrangement for such measure-

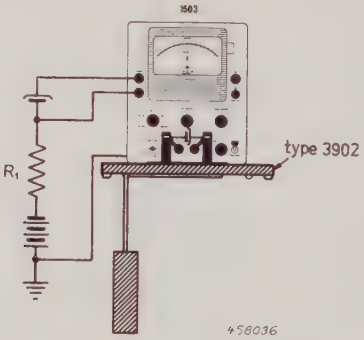


Fig. 7. Measuring arrangement for production control of electrolytic capacitors.

ments. As can be seen, a DC voltage may be applied to the capacitor under test. By connecting the DC minus to the cabinet ground terminal and the positive pole of the DC source to one of the terminals marked in white (which are interconnected) the DC voltage is applied to the "unknown" as well as the "standard". As shown in fig. 7 a resistor R_1 should be connected in series with the DC source, in order to avoid errors in the measuring result due to phase angle distortion. The resistance of R_1 in series with the internal resistance of the battery should be:

$$R_{total} > 50 \times X_c$$

where X_c is the reactance of the capacitor under test when measured at 100 c/s. However, in most cases it is not necessary to apply DC for normal measurements on electrolytic capacitors.

Checking of Transformers.

The Deviation Bridge is also a suitable apparatus for checking transformers for amplifiers, hearing aids, etc. The set-up is shown in fig. 8. The transformer with its correct load on the output side is connected to the terminals marked "Unknown". A perfect transformer loaded with the same impedance is used as standard, and defects in either coil, turn numbers or laminations

may then be observed. Also in motors, power transformers or other low-impedanced coils, the detection of shorted, open or reversed windings may be carried out by means of the Deviation Bridge Type 1503.

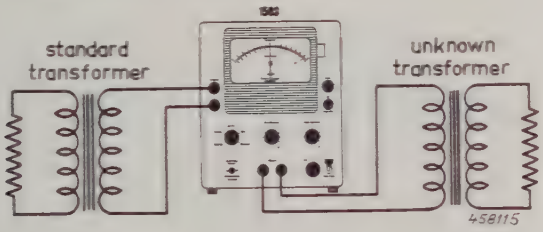


Fig. 8. Test of transformers.

Production Check of Resistors.

Production check of resistors in the range 1 Ω to 30 MΩ may be carried out by means of the Deviation Bridge Type 1503. The low working frequency of this bridge permits even large size wire-wound resistors to be checked, and the specially low output impedance of the bridge supply permits the measurement of resistances down to 1 Ω on all deviation ranges. The 8 %, 35 %, and 100 % ranges also allow measurements on resistors down to 0.3 Ω.

The practical arrangement for resistance measurements is shown in fig. 9.

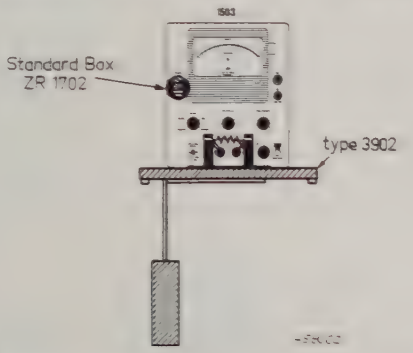


Fig. 9. Practical arrangement for resistance measurements.

Measurements of Resistors and Capacitors in Laboratories.

In laboratories where resistors and capacitors are frequently measured, it will be a practical advantage to set up a couple of measuring bridges of Type 1503 permanently connected to the resistor and capacitor standard, as indicated in fig. 10.

Resistors are measured on 1503, the "Unknown" being connected to the Bridge, and the standard resistor being varied until the Bridge is balanced. The unknown resistance can then be immediately found by reading off the

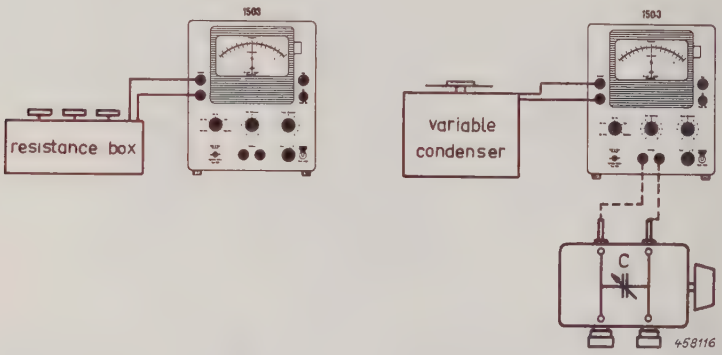


Fig. 10. Resistance box and variable capacitor connected to the Deviation Bridge Type 1503 for laboratory measurements.

value on the resistance box. This form of resistance measurement is much quicker in practice than adjusting a Wheatstone Bridge, because the meter of 1503 responds much quicker than the usual light-spot galvanometer.
Capacitors may also be measured on 1503 in exactly the same way. In order to compensate for the connections to the variable condenser and its minimum capacity, the unknown capacitor should be connected via a small extra measuring box, containing a balancing capacity. In this way, a quick and very exact measurement of capacitors can be carried out.

Direct-Reading Measurements of Capacitors.
The Deviation Bridge Type 1503 may be used as a direct-reading instrument for measuring capacitances. Two equal capacitors of exactly known capaci-

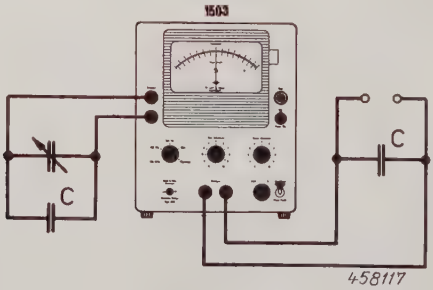


Fig. 11. Direct reading measurements of capacity values.

tances are, as shown in fig. 11, connected across the "Standard" and "Unknown" terminals, one to each terminal. The capacitance to be found is measured as a per cent increase of the fixed, known value. By choosing the fixed capacitors as pure powers of 10 the direct readings will be simplified. To make the adjustment easier it will be practical to have part of the capacitance on "Standard" placed as a small trimmer condenser.
The procedure is then as usual: Set zero point and reference, then switch to "Operation" and bring the pointer to zero in the middle of the scale by means of the adjustable part of the fixed capacitance. The following table shows an example of this type of measurement:

Example of Direct-Reading Measurement on Capacitors.

Fixed Capacitors	Direct Reading Range	Adjustment to Reference %
2 × 100 μF	0— 1.5 μF	1
	0— 8 μF	5
	0— 35 μF	20
	0— 100 μF	20
2 × 1000 μF	0— 15 μF	1
	0— 80 μF	5
	0— 350 μF	20
	0—1000 μF	20

The lowest range for direct reading is 0—15 pF.

Direct-Reading Measurements of Resistors.
In a similar way as for capacitances it is possible to use the Deviation Bridge as a direct-reading ohmmeter. As illustrated in fig. 12 two fixed resistors have to be used, but the resistance under test has to be connected in series with one of the fixed resistances. The small adjustable fraction of the other fixed R may be connected either in series or in parallel with R. If series connection is used, the adjustable R needs only be a few per cent of the total value of

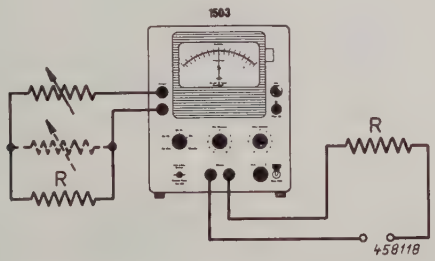


Fig. 12. Direct reading measurements of resistance values.

the fixed resistance while it has to be great compared to the total resistance if connected in parallel.
Direct reading ranges from 0—0.015 Ω to 0—10 MΩ.

Balance of Ganged Potentiometers.

For the adjustment of ganged potentiometers or variable resistors the set up shown in Fig. 13 will be practical. The two end terminals of the variable resistors are connected to the upper left and lower right terminals of the Bridge, while the moveable arms may be connected together and joined to one of the two remaining terminals. The balance expressed in % deviation may then be checked for all positions of the moveable arm. Screening of the test object avoids hum and noise pick up when potentiometers of high resistance value are tested.

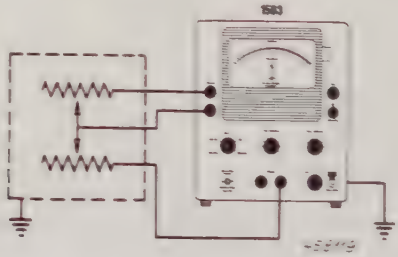


Fig. 13. Checking the balance of ganged potentiometers.

Adjustment of Air-Gaps in Choke Coils.

An arrangement as shown in fig. 14 be used to adjust the air-gap of a F

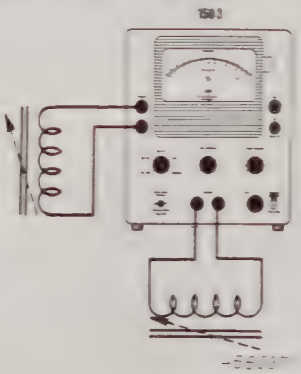


Fig. 14. Adjusting the air-gap of filter coils.

chokes or filter coils. The standard coil is placed across the "Standard" and the coil to be adjusted across the "Unknown" terminals, and the air-gap is adjusted till the meter shows zero deviation for "Impedance" measurements. Before the adjustment takes place, the coil itself can be checked to have the correct inductance without the iron core applied.

Measurements of DC Magnetized Coils.

The impedance of filter coils or LF-chokes is often measured with a certain amount of DC applied to the coil. In order to measure coils with DC applied an arrangement as seen in fig. 15 should be used. An extra pair of resistors, R_1 and R_2, are connected from the upper left and the lower right bridge terminal to ground, thereby forming a new measuring bridge outside the instrument. The standard and the unknown impedance are now connected to

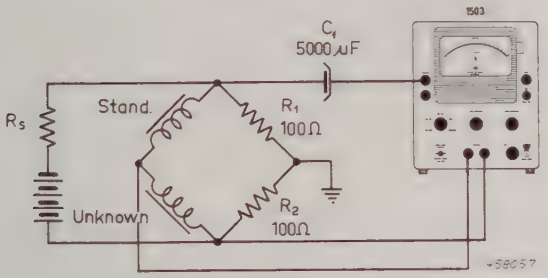


Fig. 15. Measuring LF chokes with DC applied.

the bridge arms, as seen from the figure, and their mutual point to one of the terminals marked in white. Across the bridge circuit the DC source is placed, and an isolating capacitor C_1 is applied between the bridge and the terminals of the instrument. The bridge resistors R_1 and R_2 must be completely identical to provide a perfect balance of the bridge system, the exact resistance value being of minor importance. The resistor R_s ,which is in series with the battery, avoids overload of the bridge, and regulates the current through the measuring object. To avoid extra phase shift in the bridge circuit, the reactance of C_1 must be small compared to the total impedance of the bridge system and the DC source. The reactance of C_1 must be:

$$X_c < \frac{R_{total}}{100}$$

By employing this method inductance values down to 0,05 H may be measured with DC applied.

Appendix.

Correction Data for Capacitive Loads.

Table I. When measuring large capacitors, the heavy capacitive loading of the bridge circuit will introduce a small extra phase shift in the bridge arrangement, whereby impedance and phase angle measurements will be slightly dependent of each other.

With an impedance deviation of a % and a phase angle deviation of b %, the introduced error will be as tabulated below.

Introduced Error.

Capacity to be measured	1.5 % range		8 % range		35 % range	
	Imp.	ph. ang.	Imp.	ph. ang.	Imp.	ph. ang.
up to 200 μF	0.01b	0.01a	0.01b	0.01a	0.03b	0.03a
500 μF	0.02b	0.02a	0.02b	0.02a	0.05b	0.05a
1000 μF	0.03b	0.03a	0.04b	0.04a	0.06b	0.05a
2000 μF	0.04b	0.04a	0.04b	0.04a	0.06b	0.06a
5000 μF			0.05b	0.05a	0.08b	0.08a

Syncronization of Oscillator to Line Frequency.

When the Deviation Bridge is operated from a 50 c/s power line, a beat between the frequency of the built-in oscillator and the second harmonic of the line frequency may cause disturbing fluctuations of the meter pointer. To avoid this, the oscillator is synchronized to the power line frequency, whereby beat frequencies of 0 c/s and 200 c/s are obtained, neither of which will disturb the deflection of the meter pointer.

However when the bridge is operated from f. inst. a 60 c/s power line, the synchronization signal should be short-circuited. This is obtained by means of a shorting-rod, which is inserted in a fuse-holder. The fuse-holder is placed inside the back cover, right above the pilot disc indicating the line voltage to which the apparatus is adjusted.

It should be checked that the shorting-rod is inserted when the instrument is operated from a 60 c/s power line, and that it is removed when the instrument has to be operated from a 50 c/s power line.

Specification.

Ranges of Test Components.

Resistance: 1 Ω—30 MΩ.

Capacitance: 500 pF—5000 μF (at 1.5 % range: 500 pF—2000 μF).

Inductance: 2 mH—2000 H.

Ranges of Test Components with Two External Standards and Direct Reading.

Resistance: From 0—0.015 Ω to 0—10 MΩ.

Capacitance: From 0—15 pF to 0—1000 μF.

Inductance: From 0—0.15 mH to 0—1000 H.

Measuring Frequency: 100 c/s.

Bridge Voltages: 1.5 % scale: 1.25 V, 8 % scale: 0.25 V, 35 % scale: 0.06 V, 100 % scale: 0.03 V.

Meter:

Large moving-coil instrument in which removeable scales can be inserted. Illuminated scale with zero point in the centre. The instrument is safe-guarded against overloads. Ranges for impedance deviations from — 1.5 % to 1.5 %, — 7 % to 8 %, — 25 % to 35 %, and — 50% to 100 %. Ranges for phase angle deviations from — 1.5 to 1.5×10^{-2}, — 7 to 7×10^{-2}, — 25 to 25×10^{-2}, and — 80 to 80×10^{-2} radians.

Accuracy.

Of impedance measurements: Better than 0.03 % for deviations close to zero. With zero phase angle difference between standard and unknown: Better than 3 % of indicated deviation at full scale deflection.

Stability:

The zero point is independent of the line voltage. Deflections from the zero point will change 3 % for a 10 % variation of the line voltage.

AC-Hum:

The Bridge is not sensitive to hum voltages when measuring impedances up to 1 MΩ. When measuring impedances above 1 MΩ a screening plate should be used.

Impedance - Phase Angle Switch:

A micro-switch is included to allow rapid switching from impedance to phase angle measurements.

Tubes:

2 × 6AU6 (EF94), 12AT7 (ECC81), 6AQ5 (EL90), 6X4 (EZ90), OA2 (150C2).

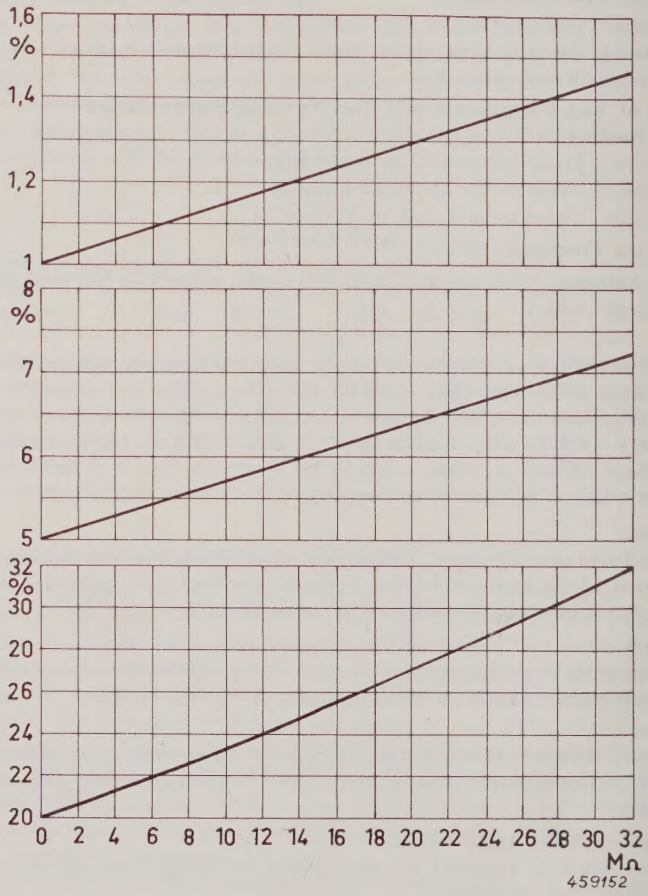
Power Supply:

115 — 127 — 150 — 220 — 240 volts AC, 40—400 c/s, 40 watts.

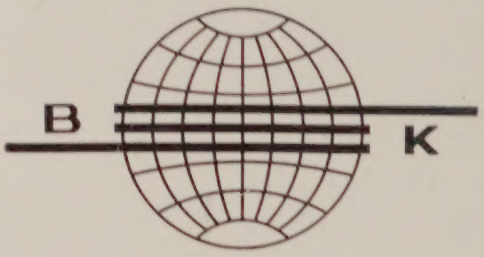
Dimensions (excl. dials and knobs): Height: 33 cm (13 inches), width: 28 cm (11 inches), depth: 20.5 cm (8 inches).

Weight: 11 kg (24 lbs.).

Correction Curves for Reference Adjustment.



Because of the increase in deviation between the "standard" and the "unknown", a simple correction curve can not be obtained for the 100 % range. The correction for this range setting, however, is within 2 % for capacitance and inductance measurements within the stated component ranges, as well as for measurement of resistance from 1 ohm to 1 Mohm.



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